APPENDIX A Odorization Technology Survey

OMB No. 004-S75002

ODORIZATION TECHNOLOGY SURVEY

Prepared by

Institute of Gas Technology

Chicago, Illinois 60616

The Institute of **Gas** Technology, Chicago, **is** currently conducting a study for the U.S. Department **a** Transportation in which it is collecting, analyzing, and evaluating data on the current state-of-the-art **a** natural **gas** odorization technology. **As** part **a** our effort **to** gather such data, we are submitting this questionnaire to numerous U.S, natural gas transmission and distribution companies. We would appreciate very much receiving this completed form **so** that the odorization practices and experiences of your company can be included in the study. Since some of the topics may require more detail, we request your permission to contact you by phone if the need arises. Space is provided on the last page for the name and phone number of the person you prefer that we contact for further information.

We have tried to make this questionnaire as brief as possible while still covering the desired material. If you have any additional information, explanations, and/or comments you wish to submit on supplemental sheets, they would be greatly appreciated.

A self-addressed, stamped envelope is included for return of the questionnaire to the Institute of Gas Technology.

If you have any questions please contact J. Adrian Chisholm at **IGT.** His phone number is (312) 225-9600, extension 659.

QUESTIONNAIRE

If the gas marketed by your company is totally for resale and is not odorized, please put a check mark in the **box** below, sign your name on the last page, and return this questionnaire to **IGT.**

Gas totally for resale; not odorized

If any portion of the **gas** in your system is considered as being odorized by naturally occurring odor or if you add odorant to any of your gas, please respond to the questions below that are applicable to your particular situation.

I. TYPE OF GAS ODORIZED

Α,	Pi	peline gas for resale, is it -	
	1.	Nonodorized?	
	2.	Odorized by odorant addition?	
	3.	Odorized by naturally occurring components?	
	4.	Odorized by odorant addition and by naturally occurring components?	

	В.	Pipeline gas for direct sale, is it -
		1. Nonodorized?
		2. Odorized by odorant addition?
		3. Odorized by naturally occurring components?
		4. Odorized by odorant addition and by naturally occurring components? □
	C.	Pipeline gas for storage, is it -
		1. Nonodorized?
		2, Odorized by odorant addition?
		3. Odorized by naturally occurring components?
		4. Odorized by odorant addition and by naturally occurring components?
	D.	Gas supplied to end user Estimated Quantity, 10 ⁶ CF/yr
		1. Quantity nonodorized
		2. Quantity of odorized gas supplied
		a. With added odorant
		b. With natural odor
II.	ODO	ORANT TYPE
	A.	Gas with naturally occurring odor
		1. If your gas contains naturally occurring odor, is it -
		a. A sulfur-type odor?
		b. A nonsulfur-type such as hydrocarbon odor?
		c. A combination of a and b?
		2. What minimum percent of gas-in-air is normally detected as a just-recognizable gas odor?
		3. Do you supplement the naturally occurring odor with odorant addition either -
		a. Continuously?
		b. Intermittently?
		c. Not necessary at any time?

	4.	If you do use supplet the chemical compos				
		Component		Percent		
	5.	What addition rate is	s used?	lb/10 ⁶ CF		
	6.		as appr	eved? (Supplementa opriate.) Equivalen or	it to)
		gas-in-air detection	1111111.			
В.	Ga	s, with no natural odd	or, to wh	nich odorant is added	Ĺ	
	1.	What odorant do you	add to y	rour gas?		
		a. Chemical comp	osition	(if known):		
		Component		Percent		
		b. Addition rate:_	1h	/106 CE		
				of gas-in-air is nor	mallv	
			_	gnizable gas odor? _	· ·	
	2.	Do you receive any o	odorized	gas from a supplier	? Y e s	
					No	
	3.	If yes, what odorant your company?	is conta	ined in the gas supp	lied to	
		a. Chemical comp	osition ((if known):		
		Component		Percent		

b. what i	_lb/10 ⁶ CF	gas as-received?	
	inimum percent of gas in ai d as a just-recognizable gas		
4. Do you suppodorant?	olement a supplier's od prize	agas with your own Yes [] No []	
5. If yes, what supplied to	is the total odorant content your customers?	of the gas b/106 CF	
6. What is you	r total odorant usage per ye	ar? 1b	
III. ODORIZATION EQU	<u>IPMENT</u>		
A. Equipment Typ	es and Characteristics		
company and your experi characteristics of up to t	types of odorization equipme ence with it. Space is provi hree types of odorant-addition in check the boxes to indicate	ded below to list the on equipment. Pleas	
Type A			
Type B			
Type C			
Characteristics of	Odorant Addition Equipmen	t Listed Above	
Ability to Maintain a Set Addition Rate	Outstanding	Type A Type B	Type C
Over the Designed	Satisfactory		
Range of Gas Flow Ra tes	Needs Improvement Unreliable		<u>о</u>

		Type A	Type B	Type C
Ease of M	Maintenance Outstanding Satisfactory Needs Improvement Unreliable			
	Checking for Outstanding Ory Operation Satisfactory Needs Improvement Unreliable	Type A	Type B	Type C
		Type A	Type B	Type C
ant Comp Changes tive Evap	From Odor- osition Such as Selec- oration of Components Outstanding Satisfactory Needs Improvement Unreliable	Type A	Type B	Type C
В.	Supplemental Odorizers			
	1. Do you use supplemental odorizers in certain portions of your system?	to increase Yes		ls
	2. If yes, are some of them in year-rooperation?	und continuc		
	3. Or, are they used on a temporary b seasons of the year or to condition r			n
	4. If yes, please explain:	Yes [] No	a

	C.	How many odorizers does your company normally operate?
		1. Fixed
		2. Supplemental
IV.	ODO	R TEST PROCEDURES
	A.	Does your company obtain an indication of the odorant concentration in gas by -
		1. Monitoring rate of leak calls per 1000 meters? Yes \(\bigcap\) No \(\Bigcap\)
		If on some other statistical basis, specify.
		Calls per Week per 1000 Meters (If for some other rate, specify) Winter Summer
		a. What rate do you experience as an average?
		b. What rate would you consider to be unacceptably high?
		c. What rate would you consider to be unacceptably low?
		d. What percentage of your leak calls is classified as "nuisance" calls (not caused by leaks requiring corrective action)?
		2. Periodic tests with odorometer, titrators, gas chromatographs, etc.? Yes No
	В,	Do you monitor odorization level with odorometers with which an operator makes a "sniff" test to determine the gas/air ratio that produces a detectable gas odor? Yes No
	C.	If yes, what type of odorometer do you use? (Please do not use brand names)

D.	What reproducibility do you experience with odorometer measurements? (If quantitative numbers are not available "Excellent," "Good," or "Poor.")	
	1, Repeat tests, same operator ±	_% gas-in-air
	Excellent Good P	oor 🗆
	2. Repeat tests, different operator ±	_% gas-in-air
	Excellent Good G	Poor
E,	Do you regularly use instruments other than odorometer level or odorant concentration testing? Yes	rs for odor No 🏻
F.	If yes, what types are employed? (Please do not use br	and names.)
	1. Titrator	
	2. Gas Chromatograph	
	a. Special Purpose	
	b. General, with sulfur-selective detector	
	3. Other (describe)	
G.	How frequently do company personnel check odor levels system by "sniff" tests? Brief answers such as "Odoro measurements are made weekly at X points in the system "All service calls include a check of the gas odor and a notation of adequacy" are sufficient.	meter mu or
н.	Do you continuously monitor odorant concentration at an your system? 1. What instruments(s) is used? 2. How many points are monitored? 3. What number of customers are in each monitored area?	y points in ☐ No ☐
I.	Are room tests or chemical tests employed for odor testing? Yes	

J. If yes, please list types of tests performed.

v. ODORANT BEHAVIOR IN SYSTEMS

Α.	Except for sections of new piping, has odor fading been observed in your system?	Yes 🗌	No 🗆
В.	If yes, is it observed -		
	1. Over the entire system?	Yes \square	No 🗆
	2. Only in specific portions of the system?	Yes 🔲	No 🗆
	3, Is it consistent enough to require permanent installations of supplemental odorizers?	Yes 🗆	No 🗌
	4. Does the fading OCCUT -		
	a. With changes in gas flow rates?	Yes \square	No 🗆
	b. With temperature changes?	Yes 🗆	No 🗆
	c. Sporadically for no apparent reason?	Yes \square	No 🗆
C.	Have you observed odor character changes in your gas without apparent reason?	Yes 🗆	No 🗆
D.	Do you have areas in your system that regularly experience mixing of gases containing different odorants?	Yes \square	No 🗆
E.	If yes, do you observe a sufficient change in odor character (not odor intensity) to affect leak call rates?	Yes 🗆	No 🗆
F.	If yes, in what direction and magnitude are the		

G.	How would you rate	the odorants in	your gas as to -	
		Satisfactory	Needs Improvement	<u>Unsatisfactory</u>
	etiveness in warning esence of gas			
Persi	stence			
Stren	gth			
Resis	stance to fading			
Resistance to loss upon soil contact				a
н.	Do you have corrosi your system that ca your gas?			
I.	If yes, please expla	in.		
J.	Do you have pipeling lecting in your systematics.		ning odorant col- Yes [] No □
K.	If yes, what is your	disposal metho	d?	

VI. GENERAL OBSERVATIONS

A. What is your opinion of the adequacy of the following areas of the Gas Industry's odorization technology?

	<u>Unsatisfactory</u>	Satisfactory but Ne e ds Improvernert	Fully Sati s fac <i>to</i> ry
Effectiveness of odorants used			
Reliability of odorant- addition equipment			
Odor-monitoring procedures			
Odor-monitoring equip-m	ent 🗆		
	y uniformity cf q ou use? If yes, ģ	quality problems with siease explain, Yes	□ No □
		v V	

C. Please list any research your company has done or has participated in regarding odorization technology.

D. What areas of odorization technology do you feel are most in need of research?

E. Do you have any comments on current Federal regulations concerning the odorization of natural gas?

Signed	Date
Title	
Company	
	tacted for further information, pleaee supply the
Name	
Title	
Phone	

When completed, please return this questionnaire in the envelope provided to -

J. A. Chiaholm
Institute of Gas Technology
3424 South State Street
Chicago, Illinois 60616

APPENDIX B

Paper on "Summary of Gas Odorants and Their Properties"

Distribution Conference May 1, 2, 3, 4, 1967 St. Louis, Missouri

SUMMARY OF GAS ODORANTS AND THEIR PROPERTIES

Ву

J. P. CENCER



MICHIGAN CONSOLIDATED GAS COMPANY

DETROIT, MICHIGAN

MAY 3, 1967

Distribution Conference May. 1, 2, 3, 4, 1967 St. Louis, Missouri

A REPORT ON SUMMARY OF GAS ODORANTS AND THEIR PROPERTIES J. P. CENCER ODORIZATION TASK GROUP MICHIGAN CONSOLIDATED GAS COMPANY DETROIT, MICHIGAN

PREFACE

This summary of **gas** odorants was prepared under the auspices of the Odorization Task Group, Chemical Services Committee, Operating Section, American Gas Association.

The data were compiled from information submitted to us by the odorant suppliers. Their cooperation on this project has made possible this listing and properties of gas odorants. We wish to thank them for their contribution to the gas industry.

The odorants listed are the more common formulations offered to the industry. Other blends are available from most suppliers. If you have conditions which require a special odorant, you will find the odorant suppliers most helpful.

No attempt has been made by the author to check or verify the data as submitted. Odorant suppliers were contacted to obtain their data and a draft of this paper was submitted for review. If there are any questions regarding odorant properties, or if there is a desire for additional information, please contact the odorant supplier. Their names and addresses are included in this report.

TABLE I

ODORANT SUPPLIERS, TRADE NAMES AND PRINCIPAL ODORANT BASE, INDEX

	ODORANI BASE, INDEX	Table	Column
	CHEVRON CHEMICAL CO., ORONITE DIVISION Executive Offices: 200 Bush Street, Son Francisco, California 94120		
Alert 101	Tertiary Butyl Mercaptan	2	3
Alert 80	Mixed Mercaptans	3	3
Ethyl Mercaptan	Ethyl Mercaptan	3	1
LPG Odorant	Mercoptons	3 5	2 1
Caledorant F	Aliphatic Sulfide	5 5	2
Calodorant B-1 Calodorant C	Mixed Aliphatic Sulfides Cyclic Sulfide	4	ī
Calodorant C Special	Cyclic Sulfide and Petroleum Factors	4	2
Calert 14	Tertiary Butyl Mercapton and Cyclic Sulfide (Bland of 2/3 Colodoron) C and 1/3 Alert 101)	6	1
Calert 30	Tertiary Butyl Mercapton and Aliphatic Sulfide (Blend of 1/2 Colodorant F and 1/2 Alert 101)	6	4
	MARSHALL HYDE INCORPORATED 1344 Gris wold Street, Port Huron, Michigan		
Formula 55	Tertiory Butyl Mercaptan	2	2
Formula 55 Special	Tertiary Butyl Mercaptan	2	3
	NATURAL GAS ODORIZING, DIV. OF HELMERICH A PAYNE, INC. Plant and General Officer: 3601 Decker Drive, Baytown, Texas 77520		
BP Capton	Tertioy Butyl Mercaptan	2	4
RP Capton	Tertiay Butyl Mercopton	2	5
TE Capton	Tertiary Butyl and Mixed Mercaptons	2	6
Capton	Mercaptans	3 3	4 5
Captan "99" DL Captan	Mercaptans Dilute Mercaptans	3	6
CS Copton	Cyclic Sulfide	4	3
CL Coptan	Dilute Aliphatic Sulfide	5	3
CS-BP Captan #11	Tertiony Butyl Mercaptan and Cyclic Sulfide	6	2
El Copton	DMS and Tertiary Butyl Mercepton	6	5
	PENNSALT CHEMICALS CORPORATION, INDUSTRIAL CHEMICALS DIVISION Throe Penn Center, Philodelphia 2, Pennsylvania		
Spotleak 1003	Tertiary Butyl Mercapton	2	8
Spotleak 1009	Tertiory Butyl Mercaptan	2	9
Spotleck 1001	Tertiary Butyl Mercopton and Alkyl Sulfide	1 3	10 7
Fuel Gas Odorant 1010 Pennodorant 1013	Ethyl Mercaptan Cyclic Sulfide	4	4
Pennodormt 1063	Cyclic Sulfido and Petroleum Fractions	4	5
Pennodormt 1005	Cyclic Sulfide and Tortiory Butyl Morcaptan	6	3
Pennodorant 1030	Aliphatic Sulfide and Mercapton	5	4
	ROBINSON BROTHERS LTD., CHEMICAL MANUFACTURERS Ryders Green, West Bromwich, England		
Tetrahy drothiophene	Cyclic Sulfide	4	6
	PHILLIPS PETROLEUM COMPANY, SPECIAL PRODUCTS DIVISION Chemical Department, Bartle sville, Oklahoma 74004		
Scentinel A	Ethyl Mercaptan, 99+% (LPG Odorant)	3	8
Scentinel C	Tertiary Butyl Mercepton	2	10
Scentine! D	Tertiary Butyl Mercapton (99±% Mercapton)	2	11
Sen noi E	Tertiary Butyl Marcapton (99+% Mercaptan)	2	12
Scenti al F	Tertiary Butyl Mercopton and Aliphatic Sulfides	2	13

_		1	2	3	4	5	6	7	
1.	Trade Name	Alert 101	Formula 55	Formula 55 Special	BP Captm RP Captan		TB Coptm	Spatieak 1001	
2	Supplier	Cal. Chem. Co. Oronlie Div.	Marshall Hyde In	c. Marshall Hyde Inc.	Natural Gas Odorizing, Inc.	Natural Gas Odorizing, Inc.	Natural Gas Odorizing, Inc.	Pennsalt Chem. Co. Ind. Chem. Oiv.	
3	Specific Gravity	0.8 10 (60°/60°F)	0.78 1 (60°F)	08 10	808.0	0.8 I?	0.810	0.8 1 (60°/60°F)	
4.	Molecular Weight, Average	86	90	90	86	86	84	83	
5.	Weight per Gallon, Lbs. @ 60°F	6.8	6.5	67 5	6.73	٤.80	6.75	68	
6.	Viscosity, Contistokes, 77 °F	0.65			, 0.502	0.467	0.84	0.6 1	
7.	Reid Vapor Pressure, psia @ 100° F	6.8			5.0	8.1	4.2	8.7	
8.	Distillation	IBP 132°F 5% 137°F 50% 145°F 95% 157°F	18P 134°F 5% 140°F 50% 141°F 95% 148°F EP 158°F	18P 145°F 5% 150°F 50% 156°F 95% 180°F EP 194°F	18P 136°F 5% 139°F 50% 142°F 95% 147°F EP 160°F	IBP 118°F 5% 128°F 50% 138°F 95% 160°F EP 365°F	IBP 13 F 5% 137 °F 50% 140 °F 95% 150 °F EP 156 °F	IBP 122° F FBP 156° F	
9.	Volatility	80 lbs, per MMCF (0°F, 1,000 psi)			350 lbs. por MMCF (0°F, 1,000 psi)	70 lbs. per MMCF (0°F, 1,000 psi)	500 lbs. per MMCF (0°F. 1,000 psi)	423 lbs./MMCF (40°F, 720 prig)	
0.	Cloud Point	-20°F			-20°F Mox.	•20°F Max.	-20°F	Less than -20°F	
1.	Freezing Point	Bolow -60°	-20°F or lower	-20°F or lower	Below -60°F	Below -60°F	Below -60°F	Below -70°F	
2.	Flash Paint (open cup)	10°F			20 ° F	20°F	20°F	Below 0°F	
3.	Morcaptan Content, Per Cent	97%(vol.)	85% min. (wt.)	80%min. (w1.)	W +% (vol.)	80% (vol.)	99 +% (vol.)	80%	
14.	Sulfur Content, Weight Per Cent	37%	29%	35%	37%	37%	36%	38%	
5.	Solubility in Water	0.3 wt. per cent e 68° F	nil	nil	Trace	Trace	Troce	Negligible	
16.	Recommended Odoriring Rotos: Natural Cos	025 • 1.0 ibs.	0.25 - 0.50 lbs.	0.25 ⁼ 0,50 {bs. per MMCF	0.25 - 10 lbs. pಈ MMCF	0.25 - 1.0 lbs. por MMCF	025 • 10 } bs. per MMCF	0.25 - 0.75 lbs.	
	L-P Gas	10 I b./10 M gal.							
17.	Sulfur Contribution, Groins/100 cu. ft.	0.26 grains @ 10 lbs/MMCF	0.1 grains @ 05 16./MMCF	0.1 @ 0.5 lbs./MMCF	0.26 @ 1.0 Ibr.	0.26 grains @ 10 (b./MMCF	0.25 grains@ 10 ib./MMCF	0.07 • 0.20 grains 0 025 • .75 lb./	
18.	Typical Composition	80% TBM	85% TBM	80% TBM 20% other RSH	77% TBM ' 23 % other RSH	80% TBM 20% DMS	55% TBM 45% other RSH	80% TBM 20% AS	
19.	Titralog Factor	27.4	31.2	_	19.60	280	18.45	24.2	
ก	Barton Titron Factor "C", Ronge 1 ma	.058	.06 1	-	.06 1	.069	.071	.058	

TABLE !! (Continued)

LISTING AND PROPERTIES OF ODORANTS WITH TERTIARY BUTYL MERCAPTAN AS THE PRINCIPLE BASE

		8	9	1.0	11	12	13
1. To	rade Name	Spotleak 1003	Spotleak 1009	Scantinel C	Scentinel D	Scantinel E	Scantinel F
2 Si	upplier	Pennsalt Chem. Co., Ind., Chem., Div.	Pennsalt Chem. Co. Ind. Chem. Div.	Phillips Petro, Co. Special Products Div.	Phillips Petm. b . Special Products Div.	Phillips Petm. 6. Special Products Div.	Phillips Petro. 6 - Special Products Div.
3. S	pecific Gravity	0.81 (60°/60°F)	0.8 1 (60°/60°F)	0.78	0.8 1	0.8 1	0.82
4. M	olecular Weight, Äverage	86	a6	89	90	87	84
5. W	Veight per gallon, ibs. @ 60°F	6.74	6.76	6.5	6.74	6.74	6.81
I	iscosity, Centistoke, 77°F	0.65	0.64	0.65	0.68	0.66	0.59
7. R	Reid Vapor Pressure, psia @ 100°F	7.3	6.6	6.9	6.8	7.0	8.4
8. D	Distillation	IBP 131°F	I BP 131°F	18P 137 5% 141 50% 145 '95% 151	IBP 145 5% 156 50% 177 95% 187	1BP 138 5% 144 50% 151 95% 154	IBP 125 5% 130 50% 141 95% 160
		FBP 158°F	FBP 167°F	3570 151	3370 IOI	3370 134	33 /0 100
9. ∨	'olatility	444 lbs . per W C F (40°F, 720 psig)	378 lbs. per MMCF (40° F, 720 psig)	78 lbs. per MMCF (0°F, 1,000 psi)	88 lbs. per MMCF (0°F, 1,000 psi)	:	93 lbs. per MMCF (0°F, 100 lbs.)
10. C	Cloud Point	Loss thon - 20°F	Less than -20°F	-30	-35°F	- 25°F	- 25°F
11. F	reezing Point	Below - 50° F	Below -50 °F	-30	-50 °F	- 40°F	Below -40°F
12 F	Flash Paint (open cu) F	0°F	Below OF	0	0°F	Below 0°F	Below OrF
13. M	lercoptm Content. Per Cant	97% (vol.)	97%min. (vol.)	85	99 t	99 +	75% TBM
14. S	Sulfur Content, Weight Per Cent	35.8%	35% min.	31.4	37	37	38
15. S	Solubility in Water (% by vol.)	Negligible	Negligible	0.5	0.5	0.5	0.4
	ecommended Odarizing ates: Natural Gas	0.25 to 0.75 lbs.	0.25 to 0.75 lbs.	0.3 to 1.0 lbs.	0.3 to 10 lbs.	0.3 to 1.0 lbs.	0.3 to 1.0 lbs./MMCF
	L-P Gas	poi iviivice	per minici	per ivilvici	per minici	por white	
17. St	ulfur Contribution, Grains/100 cu.ft.	0.06 to 0.19 grains @ 0.25 to 0.75 lbs./MMCF	0.06 to 0.18 grains @ 0.25 to 0.75 lbs./MMCF	0.07 to 0.22	0.07 to 0.25	•	0.07 to 0.25
18. T	ypical bmposition	76.5% T BM 23.5% other RSH	80%TBM 20%other RSH	85% TBM 15% Alip, Hydrocarbon	80% TBM 20% other RSH		75% TBM 25% Aliphatic Sulfide
19. T	itrolog Factor	24.2	23.8	18.2	16.7	246	21.7
20. B	Borton Titron Factor "C", Range 1 ma	.058	.058		.061	.08	

3-8

TABLE III

LISTING AND PROPERTIES OF ODORANTS WITH

MERCAPTAN BASES OTHER THAN TERTIARY BUTYL MERCAPTAN

	1	2	3	4	5	6	7	8	
1 Trade Name	Ethyl Mercaptan LPG Odorant		Alert 80 Captan		Captan ''99''	DL Captan	Fuel Gas Odorant 1010	Scentinel "A"	
2. Supplier	Chevron Chem. Co.	Chevron Chem. Co. Oronite Division	Chevron Chem. Co. Oronite Division	Natural Gas Odoriring, Inc.	Natural Gas Odoriring, Inc.	Natural Gos Ddoriting, Inc.	Pennsalt Chem, Co. Ind. Chem, Division	Phillips Petro, Co. Special Products Div.	
3 Specific Gravity	0.844 (60°/60°F)	08 16 (60°/60°F)	0.8 <i>2</i> 9 (60°/60°F)	0.825	0.820	0.695	0.84	0.84	
4 Molecular Weight, Averag	• 62	76	77	82	82		62	62.1	
 Weight p Gallon, Pounds 60 F 	7.0	6.8	6.9	6.88	6.83	5.84	7.0	7.02	
6. Viscosity, Centistakes 77	7°F 026	0.40	0.44	0.410	0.401	0.393	0.28	0.28	
7. Reid Vopar Pressure,	16.0	88	9.1	8.2	6.8	8.0	16.5	40.0	
•							0.01	16.2	
8. Distillation	5% 95°F	5% 124°F	1BP 103°F 5% 120°F	18P IP'F 5% 125°F	IBP 1 28°F 5% 130°F	IBP 142° F 5% 145° F	1% 94 °F	IBP 95.0°F 5% 95.4°F	
В	50% 96°F 95% 97°F	50% 127 ° F 95% 130° F	50% 1 44°F 95% 192°F	<i>50</i> % 130°F 95% 148°F	50% 139°F 95% 138°F	50% 1 50°F 95% 159°F	95% 98°F	50% 95.4° F 95% 96 ,0°F	
9				EP 170°F	EP 149°F	EP 162° F	30,0		
9. Volatility	250 lbs/MMCF (0°F, 1,000 psi)	145 lbs/MMCF (0°F, 1.000 psi)	90 lbs/MMcf (0°F, 1,000 psi)	210 lbs/MMef (OF, 1,000 psi)	100 lbs/MMcf (0°F , 1,000 psi)	28 Gals/MMcf (0°F, 1,000 psi)	700 lbs./MMcf (40°F.,720 psig)	230 lbs./MMcf (0°F. 1,000 psi)	
10. Claud Point	-20° F	-20°F	-20°F	-20°F	-20°F	- 10°F		-20°F	
11. Freezing Point	Below - 150°F	Below -150°F	Below ~ 100°F	Below - 100°F	Below -100°F	Below -100°F	Below -50°F	Below -200°F	
12. Flash Point (Open Cup)	Below 0° F	Below OF	Below 0°F	Below 20°F	20 ° F	0°F	Below 0°F	-55° F	
13. Mercaptan Content, Volume Per Cent	99+%	99+%	95%	90%	99+%	10%	98%	99+%	
14. Sulfur Content, Weight Per Cent	52%	42%	42%	36%	36%	4.1 %	52%	51%	
15. Solubility in Water	0.70 wi. per cent 9 68 ° F	0.26 wt. per cant @ 68°F	0.38 wt. per cent e 68°F	Trace	Tmce	Trace	Negligible	1% 0 77' F (by vol.)	
16. Recommended Odorixing Rates: Natural Gas L-P Gas	1.0 lbs/10,000 Gal.	10 16s/10,000 Gal.	0.25-1.0 bs/MMef 10 bs/10,000 Gal.	0.25-1.0 bs/MMcf	0.25-1.0 lbs/MMcf	0.25-1.0 lbs/MMcf	1.0 lbs/10,000 Gal.	1.0 lb 1/10,000 Gal. Minimum	
17. Sulfur Contribution, Grains/100 cu. ft.			0.29 grains @ 1.0 Ib. per MMcf	0.25 grains@ 1.0 lb per MMcf	0.25 grains @ 1.0 lb. per MMcf	0.173 groins 10 Gal. per MMcf		.98 grains ऒ Min. Rate	
18. Typical Composition	99+% Ethyl Mercaptan	99+% Mercaptans	95% Mercaptans	90% Mercaptans 10% DMS	99+% Mercaptans	10% Mercaptans 90% Hydrocarbons	Ethyl Mercaptan	99+% Ethyl Mercaptan	
19. Titralog Factor	mer experient		17.6	15.4	16.20	90% Hydrocarbons		7.4	
20, Barton Titron Factor, Rongor 1ma			.ox		.030				

TABLE 1V

LISTING AND PROPERTIES OF ODORANTS WITH CYCLIC SULFIDES AS THE PRINCIPAL BASES

	1	2	3	4	5	6	
1. Trade Name	Calodorant C	Calodormt C Spec. C\$ Coptan		Pennodorant 1013	Pennodorant 1063	Tetrahydrothiophene	
2 Supplier	Chevron Chem. Co. Oronite Division	Chevron Chem, Co. Natural Gas Oronite Div. Odorizing. Inc.		Pennsalt Chem. Co. Ind. Chem. Div.	Pennsalt Chem, Co. Ind. Chem, Div.	Blobins Horbitas to Lind.	
3. Specific Gravity	1.00 (60°/60°F)	0.078 (60°/60°F)	0.999	1.00 (60°/60°F)	0.868880 (15.5°/15.5° C)	1.00 (60°/60° F)	
4 Molecular Weight, Avg.	aa	95	88	88	93	88	
5 Weight/Gol. lbs. @ 60° F	8.3	7.3	8.32	8.33	7.2	8.3	
6. Viscosity, Centistokes 77 F	0.94	0.82	0.775	0.94	0.84	0.94	
7. Reid Vapor Pressure, psia @ 100°F	1.01	0.98	0.8 '	1.0	10	10	
8 Distillation	1BP 170°F 5% 210°F 50% 24PF	IBP 216°F 5% 235° F 50% 244° F	IBP 245° F 5% 250° F 50% 2ST F	18P 239°F	IEP 230°F	5% 241°F	
	95% 248° F	95% 260°F	95% 252° F EP 255° F	95% 253% FBP 256%	95% 260°F	9 <i>5</i> % 254° F	
9. Volatility	12 bs/MMcf (0°F, 1,000 psi)	1216s/MMcf (0°F. 1,000 psi)	64 lbs/MMcf (0°F, 1,000 psi)	38 lbs/MMcf (40° F , 720 psig)	69 lbs/MMcf (40°F, 720 prig)		
D. Cloud Point	-20°F	-20° F	-20°F	-20° F (Max)	Lass thon -20°F		
11. Freezing Point	Below - 100° F	Below - 100°F	Below - 100°F	Bolow -50°F	Below-50°F	-141.2°F	
12 Flash Point (Open Cup)	60°F	80° F	Loss than 20°F	55°F	69°F	64°F	
13. Mercaptan Sulfur Content, w?%			0%	0.1% (Max.)	0.1% (Moa.)	Negligible	
4. Sulfur Content, Weight %	37%	10.6%	36%	37 %	P.3 (Mor)	36.4%	
15. Solubility in Water	0.07 wt, per cent @ 68°F	0.06 wt, per cent e 68°F	Trace	Negligible	Negligible	0.07 wt. pacent	
16. Recommended Odoriring Rotos: Natural Gas L-P Gos	0.25 10 lbs/MMcf 10 lb., 10,000 Gal.	0.5-1.5 lbs/MMcf	0.5-1,0 lbs/MMcf	0.25-1.0 1bs/MMcf	0.5-1.5 lbs/MMcf	0.5-1,0 lbs/MMCF	
17. Sulfur Contribution, Grains/100 cu. ft.	0、26 grains @ 1.0 Ib/MMCF	0.14 groins @ 10 Ib/MMcf	0.245 grains @ 10 lb/MMcf	0.07-0.20 groins@ 0.25-1.0 lb/MMcf	0.671051 b.gràins @	0.13-0.26 groins @ 0.5-1.0 lbs/MMcf	
18. Typical bmposition	Cyclic Sulfide	Cyclic Sulfide and Pot. Fraction	100% Tetrahydrothiophene	Cyclic Sulfide	55%Cyclic Sulfice 45% Petroleum Fraction	97% Tetrahydrothiophene	
19. <i>Titralog</i> Factor	23.3	37.05	20.80	21.5	38.0		
20. Barton Titron Factor, Range 1 ma	.077		.082	.082		.062	

TABLE V LISTING AND PROPERTIES OF ODORANTS WITH ALIPHATIC SULFIDES AS THE PRINCIPAL BASES

	1	2	3	4
1. Trade Name	Calodorant F	Calodorant E1	CL Captan	Pennodormt 1030
2 Supplier	Chevron Chem, Co. Oronite Div.	Chevron Chem, Co. Oronite Div.	Natural Gas Oderizing, Inc.	Pennsalt Chem. Co. Ind. Chem. Div.
3. Specific Gravity	0.849 (60°/60°F)	0.839 (60°/60°F)	* * *	.85
4 Molecular Weight, Average	64	98	8-4	64
5 Weight per Gallon, pounds @ 60°F	7.1	7.0	5.76	7.1
6. Viscosity, Centistokes, 77°F	0.34	0.51	0.478	. 27
7. Reid Vapor Pressure, psia@ 100°F	15.0	2 10	11.5	14
8. Distillation	IBP 98°F	IBP 156°F	IBP 128°F	18P 97°F (Min.)
	5% 100°F 50% 103°F 95% 124°F	5% 197°F 50% 228°F 95% 277°F	5% 135°F 50% 1 50° F 95% 160°F EP 170°F	F8P 156°F (Mor.)
9. Volatility	215 lbs/MMcf (0°F, 1, OWpsi)	18 lbs/MMcf (0°F, 1,000 psi)	24 gals/MM cf (0 °F, 1,000 psi)	1100 lbs/MMcf (40°F, 720 psig)
O. Cloud Point	−20° F	−20°F	-10°F	-20°F Max.
T. Freezing Point	Below -100°F	Below = 100°F	Below - 100° F	Below -50°F
12 Flash Point (Open Cup)	Below -30° F	30° F	0°F	Below 0°F
3 Mercapton Content, Volume Per Cent			Trace	
4. Sulfur Content, Weight Per Cent	50%	32%	4.1%	49.5%
5. Solubility in Water	0.3 wt per cent @ 68° F	0.1 wt per cent @ 68°F	Trace	Negligible
16 Recommended Odorizing, Rates: Natural Gos L-P Gas	0.25-1.0 lbs/MMcf 10 lb/10,000 gals.	0,25-1,01bs/MMef 10 "lb/10,000 gals.	0.25- 10 Gals/MMcf	025-1.0 lbs/MMcf
17. Sulfur Contribution, Grains per 100 cu. ft.	0.35 grains @ 1.0 lb/MM cf	0.22 grains @ 1.0 lb/MMcf	0.173 groins € 1.0 gal/MMcf	0.35 grains @ 1 lb/MMef
& Typical Composition	Aliphatic Sulfide	Mixed Aliphatic Sulfides	10% DM\$ 90% Hydrocarbons	90% Aliphatic Sulfide 10% Mercoptm
9, Titralog Factor	16.0	23.5		
© , Barton Titron Factor, R ong 1 ma	.067	.090		

TABLE VI

LISTING AND PROPERTIES OF ODORANTS WITH MIXED ODORANT BASES

	1	2	3	4	5	
1 Trade Name	Calert 14	CSBP Captan #11	Pennodormt 1005	Calert 30	El Capton	
2 Supplier	Chevron Chem, Co. Oronite Div.	Natural Gas Odoriring, Inc.	Pennsalt Chem. b. Ind. Gem. Div.	Chevron Chem. Co. Oronite Div.	Natural Gas Odorizing Co.	
3. Specific Gravity	<i>0.</i> 937 (60°∕60°F)	0.905	0.93 (1 5.5°/15.5°C)	0.830 (6 0 °/6 0 °F)	0.829 (60°/60°F)	
4 Molecular Weight, Average		87	88.8		77	
5. Weight/Gal., lbs@60°F		7.54	7.7		6.90	
6. Viscosity, Centistokes 77°F		0.650	0.94		.467	
7. Reid Vapor Pressure psia @ 100°F		3.0	4.5		8.1	
8. Distillation .	5% 184°F 95% 249°F	IBP 150°F 5% 162°F 95% 250°F EP 260°F	IBP 140° F 95% 256° F	5% 1 15°F 95% ኤምF	1BP 110°F 5% 113°F 50% 122°F 95% 150°F EP 153°F	
9. Valatility		550 lbs/MMcf (0°F, 1,000 psi)	57 lb./MMCF (40°F, 720 psig)		70 lbs. per MMc (0°F, 1000 psi)	
D. Cloud Paint	-25° F	-20° F	-20° F	25 ° F	−20°F	
1. Freezing Point		Bolow -90°F	Below -50°F		Below -60°F	
2 Flash Point (Open Cup)		35°F	25° F		20 ° F	
3. Morcaptan Content, Vol%	33%	50%	39%	55%	50%	
4. Sulfur Content, Weight -%		37%	35.8%		41.5%	
5. Solubility in Water		Trace	· Negligible		Negligible	
 Recommended Odorizing Rates: Natural Gos L-P Gas 		0.50-1.0 lbs/MMcf	0.25-0.75 lbs/MM cf		4251.0 lbs/MM	
7. Sulfur Contribution, Grains/100 au ft.		0.25 grains @ 10 lb/MMcf	0.06-0.19 grains @ 0.25 0.75 lb/WMcf		, 295 grains @ 10 lb. MMcf	
8. Typical Composition	67% CS 26% TBM 7% RSH	55% THT 35% TBM 10% RSH	67% C\$ 33% TBM	45% AS 40% TBM 15% RSH	52% DMS 48% TBM	
9. Titralog Factor						
0, Barton Titron Factor, Rmge 1 ma						

NOTE: CS-Cylic Sulfido, THT-Tetrahydrothiaphene, TBM-Terriary Butyl Mercaptan, RSH-Mixed Mercaptans, AS-Aliphatic Sulfide.

APPENDIX C

Commercial Gas Odorants and Relative Odor Contribution (Source: Heath Consultants Inc.)



COMMERCIAL GAS ODORANTS & RELATIVE ODOR CONTRIBUTION

KEY TO ODDRANT CHART. This chart presents the composition and relative odor contribution of each common commercial odorant. In the extreme left hand column, each commercial odorant is listed by tist rade name and manufacturer. Across the top are listed the ten most commonistiful composition of each commonistiful composition of each commonistiful composition of each commonistiful gas based on the addition of one pound of the commercial odorant is listed by tist rade name and manufacturer. Across the top are listed the ten most commonistiful composition of each commonistiful gas. The third, labeled "ppm relative", denotes the commonistiful composition of each commercial odorant is but that contribute no odor, such as: hexage, methanol, and the iso parafilms are included under "balance," as well as other sulfur bearing compounds. Under each component, three values are given: The first, labeled "ppm actual," denotes the resulting at the American Society of Heating, Refrigerating, and Air Conditioning Engineers meeting in Chicago, Illinois and a time American Society of Heating, Refrigerating, and Air Conditioning Engineers meeting in Chicago, Illinois on fatural gas. The third, labeled "ppm actual is a the American Society of Heating, Refrigerating, and Air Conditioning Engineers meeting in Chicago, Illinois or natural gas. The third, labeled "ppm actual," denotes the resulting and the Air Conditioning Engineers meeting in Chicago, Illinois or natural gas that would yield an odor service equivalent to that concentration of Tetracry Burly Mercal (TBM) in part of the Composition of each commencial odorant is all the American Society of Heating, Refrigerating, and Air Conditioning Engineers meeting in Chicago, Illinois and the Air Conditioning Engineers meeting on fault and Air Conditioning Engineers meeting on fault and the Air Conditioning Engineers meeting on fault and Air Conditioning Engineers meeting of the composition of each compos

ODORANT	ETHYL MERCAPTAN	Di METHYL SULFIDE	ISO PROPYL MERCAPTAN	NORMAL PROPYL MERCAPTAN	METHYL ETHYL SULFIDE	TERTIARY BUTYL MERCAPTAN	SECONDARY BUTYL MERCAPTAN	Di ETHYL SULFIDE	THIOPHANE	ETHYL ISOPROPYL SULPHIDE	BALANCE	TOTAL EOUIVALENT ODORANT
NGO ETHYL MERCAPTAN PW SPOTLEAK 10:0 PP SCENTINEL A NGO LP CAPTAN	98min 5.66 6.11 100 5.78 6.24 99 5.72 6.18 90 5.20 5.62	E ACTUAL RELATIVE	% PPM [®] PPY [®] **ACTUAL RELATIVE	% PPM (1) PPM (2) ACTUAL RELATIVE	% PPM® PPM® ACTUAL RELATIVE	% PPM ^① PPM ^② **ACTUAL RELATIVE	PPM [®] PPM [®] ** ACTUAL RELATIVE	% PPM ^① PPM ^② ACTUAL RELATIVE	% PPM ① PPM ② ACTUAL RELATIVE	PPN [⊕] PFN ^② ** ACTUAL PELATIVE	% % % ③ SH S	6.11 6.24 6.18 6.21
PP SCENTINEL C-90 NGO SM CAPTAN PP SCENT YE, F-90 PW PENNODORANT '030 PW PENNODORANT '326 NGO EL CAPTAN PP SCENTINEL F-50 PW SPOTLEAK 1410 NGO CAPTAN 99 PP SCENTINEL P PW SPOTLEAK 1440 NGO CAPTAN PP SCENTINEL C-10 PW SPOTLEAK 1450 NGO CAPTAN (V) PP SCENTINEL O NGO SM CAPTAN (V) NGO SM CAPTAN (V)	15 .87 .94	90 5.20 5.25 90 5.20 5.25 90 5.20 5.25 90 5.20 5.25 965 5.0 5.05 50 2.89 2.92 50 2.89 2.92 50 2.89 2.92 10 58 59 10 .58 59	80 3.77 3.32 80 3.77 3.32 80 3.77 3.32 70 330 2.90 70 3.30 2.90 70 330 2.90 70 330 2.90 70 330 2.90	10 .47 .40 10 .47 .40 10 .47 .40 10 .47 .40 10 .47 .40 7 .33 .28 10 .47 .40 21 .99 .84	10 .4? .31 90 4.24 2.80 50 2.36 1.56	10 .40 .40 10 .40 .40 10 .40 .40 50 1.99 1.99 50 1.99 1.99 50 1.99 1.99 10 .40 .40 10 .40 .40	3 .l2 .24 9 .36 .72				1 1	5.66 5.65 5.65 5.61 4.91 4.91 4.92 4.12 4.12 4.12 4.12 4.12 4.29 4.29 4.41 4.01 4.70 + 3.20 355
PW SPOTLEAK 1001 PP SCENTINEL C PW SPOTLEAK 1096 NGO RP CAPTAN NGO RP CAPTAN NGO CP CAPTAN PW SPOTLEAK 1009 PP SCENTINEL D PP SCENTINEL F-20 PP SCENTINEL N NGO BP CAPTAN (V) PW SPOTLEAK 1420 PW SPOTLEAK 1425 PP SCENTINEL E PP SCENTINEL E PP SCENTINEL F-25 PW SPOTLEAK 1085 PP SCENTINEL F-25 PP SCENTINEL F-35 PP SCENTINEL G **CONTINEL F-35 **C	}	20 1.16 1.17 20-25 116 1.44 117 1.45 20 1.16 1.17 24 1.39 1.40 25 1.44 1.45 34 1.96 1.98 36 2.08 2.10	1 .05 .04 15 .71 .62 15 .71 .62 14-20 ⁶⁶ ⁹⁴ ⁵⁸ ⁸³ .2 15 .71 .62 15 .71 .62 15 .71 .62 15 .71 .62 7 .33 .29	6 .28 .24 2-6 .28 .24 2-6 .28 .24 6 .28 .24 6 .28 .24 2 .09 .08 4 .19 .16	0-25 94 1.18 62 70 7 7	80 3.18 318 78 311 311 80 3.18 318 75-80 299 3.8 299 3.8 75-80 299 3.8 299 3.8 75-80 299 3.8 299 3.8 75-80 299 3.8 314 79 3.14 3.14 79 3.14 3.14 79 3.14 3.14 76 3.03 3.03 75-77 299 3.07 299 3.07 76 3.03 3.03 76 3.03 3.03 78 3.11 3.11 75 2.99 2.99 74 2.95 2.95 65 2.59 2.95 65 2.59 2.59 64 2.55 2.55 55 2.19 2.19 24 .96 96	3 .12 .24 15 .60 l.19 14 .56 l.11	80 3.18 70	100, 407, 5.63	10 .34 .07	14 1 20 20 20 25 4 1	4.35 3.63 + 3.18 4.16 - 4.63 2.69 = 3.98 4.00 4.49 + 4.31 + 4.13 3.65 - 4.46 4.43 4.13 3.97 + 2.99 4.40 + 4.57 + 4.00 + 4.65 4.05 1.31 1.19 1.11 1.63 +
NGO CS CAPTAN PP SCENTINEL T PW PENNODORANT 1013 NGO CS CAPTAN 2*5% METHANOL; PP SCENTINEL T - 97 PW PENNODORANT 1073 NGO CAPTAN 21 PP SCENTINEL T - 70 PW PENNODORANT 1005 NGO CS CAPTAN 60 PP SCENTINEL T - 55 PW PENNODORANT 1063	} } } }					30 1.19 1.19 30 1.19 1.19 33.5 1.33 1.33			100 4.07 6.63 100 4.07 6.63 100 4.07 6.63 97.25 3.96 6.45 97 3.95 6.44 70 2.85 4.65 70 2.85 4.65 66.5 2.71 4.42 60 2.44 3.98		2.75 2.75 3 40 45 45	6.63 6.63 6.45 6.45 6.45 6.44 5.84 5.75 3.98 3.65

NGO NATURAL GAS ODORIZING CO

PENNWALT CORP

PHILLIPS PETROLEUM CO (SCENTINEL)

① PPM ACTUAL PER POUND OF ODORANT/ MMCF

⁽²⁾ PPM EQUIVALENT TO T.B M ODOR CONTRIBUTION PER POUND OF ODORANT/ MMCF 3 NON ODORANT-DILUTANTS HEXANE, METHANOL, ISOPARAFFINS

References Cited

- 1. Hilt, L., 'Chronology of the Natural Gas Industry,' Amer. Gas J. 172, 29-36 (1950)May.
- 2. Senatoroff, N. K., "Odorization Practices," A. G. A. Proc. 1950, PC-50-20.
- 3. Katz, S. H. and Allison, V. C., "Stenches for Detecting Leakage of Blue Water Gas and Natural Gas," Tech. Paper 267. Washington, D. C.: Bureau of Mines, J. S. Department of the Interior, 1920.
- 4. Fieldner, A. C.- 'al,, "Warning Agents for Fuel Gases," Monograph 4. Washington, D. ... Bureau of Mines, U.S. Department of the Interior, May 1931.
- **Cox**, R. O., "Developments in Natural Gas Odorization," <u>Gas Age 94</u>, 69-71, 107-8, 110 (1944) October 5.
- 6. Gill, C. E., "History and Purpose of Gas Odorization." Paper presented at IGT Odorization Short Course, Chicago, June 1965.
- 7. Deininger, N. and McKinley, R. W., "Investigation of Newodorants for Natural Gas," Interim Rep. No. 1, A. G. A. Gas Prod. Res. Rep. Arlington, Va., May 1953.
- 8. Kendall, D. A. and McKinley, R. W., "Development of Unique Odorants for Natural Gas," A.G.A. Gas Prod. Res. Rep. Arlington, Va., May 1953.
- 9. McKinley, R. W. and Larratt, A. E., "Study of Commercial Odorants for Natural Gas," A.G.A. Gas Prod. Res. Rep. Arlington, Va., May 1954.
- McKinley, R. W. and McDowell, I. T., "Development of New Odorants for Natural Gas," and "Effect of Gas Odorant Adjuncts on the Odor Profiles of Natural Gas Odorants," A. G. A. Gas Prod. Res. Rep. Arlington, Va., August 1955.
- 11. Gieruszczak, T. E., "Merits of Mercaptan-Sulfide Blends as Odorants,"

 A.C.A. Oper. Sect. Proc. 1964, 64-P-166.
- Olsen, A. W., "Merits of Sulfide-Mercaptan Blends as Odorants," A. G. A. Oper. Sect. Proc. 1964, 64-P-169.
- Olund, S. A., "Merits of Sulfide-Mercaptan Blends as Odorants," A. G. A. Oper. Sect. Proc, 1964, 64-P-171.

- 14. Baum, E. O., "The Merits and Chemistry of Basic Odorants," in "Proceedings of the Twenty-Fourth Annual Appalachian Gas Measurement Short Course 1964," Tech. Bull. No. 73, 499-500. Morgantown: West Virginia Univ., February 1964.
- 15. Nevers, A. D., "The Chemistry of Commercial Gas Odorants." Paper presented at IGT Odorization Short Course, Chicago, June 1965.
- 16. Fitzgerald, W. J., "Physical Properties of Odorants," ibid.
- 17. Roberson, S. T., "Chemical and Physical Properties of Odorants." Paper presented at IGT Odorization Symposium, Chicago, March 1971.
- 18. Blair, B. C., "Odorization of LPG and Natural Gas. Odorant Characteristics and Properties," in Proceedings of the Forty-Ninth International School of Hydrocarbon Measurement, 114-16. Norman: Univ. of Oklahoma, 1974.
- 19. Natural Gas Odorizing., Inc., Organization Manual. Houston, n. d.
- 20. Holtz, L., "Odorization of Natural Gas," Proc. Pac. Coast Gas Assn. 21, 303-13 (1930).
- 21. Powell, J. S., "Selection of an Odorant for Natural Gas Odorization," Proc. Pac. Coast Gas Assn. 41, 134-38 (1950).
- 22. Loper, B. H., "Odorization From the Customers Service Department Viewpoint," A. G. A. Proc. 1956, CEP-56-12.
- 23. Cofield, W. W., "Criteria to Consider When Setting Specifications for Odorants," A. G. A. Oper. Sect. Proc. ~ 1966, 66-P-494.
- 24. Kyhos, B., "Odorization for Distribution Systems," Gas Age 133, 31-33 (1966) August.
- 25. Calaway, M.E., Smith, C. D. and Woolfall, G. E., "Odorization (Panel)," in Proceedings of the Forty-Fifth Southwestern Gas Measurement Short Course, 183-88. Norman: Univ. of Oklahoma, 1970,
- 26. Lehman, E. A., "Selection of an Odorant." Paper presented at IGT Odorization Symposium, Chicago, March-April 1971.
- 27. Holtz, L., op. cit.
- 28. Parker, R. W., "Survey of Odorizing Practice in Gas Transmission," Petrol. Eng. 12, No. 10, 14, 114, 116, 119, 120 (1941).
- 29. Powell, op cit.
- 30. Johnson, E. E., "New Developments in Odorants, " A. G. A. Proc. 1950, PC-50-21.

- 31. Johnson, E. E., ibid.
- Whitehead, A. L., "Experiences With Major Changes in Ddorization Practices," A. G. A. Oper. Sect. Proc. 1970, 70-D-32.
- 33. Heath Consultants Inc., Commercial Gas Odorants and Relative Odor Contribution. Stoughton, Mass., 1973.
- 34. Henderson, **E.** L., "Odorization of Gas," A.G.A. Proc. 1952, DS-52-1.
- 35. Buczek, L., "Operation and Maintenance of Gas Odorizing Equipment," in "Proce diags of the Twenty-Fifth Annual Appalachian Gas Measurement Short Course 1965," Tech. Bull. No. 77, 237-57. Morgantown: West Virginia Univ., "Sruary 1966.
- 36. Detert, F. L., "Evaporation Odorizers." Paper presented at the IGT Odorization Symposium, Chicago, March 1971.
- 37. Lincoln, J. E., "Liquid Injection Odorizer Installations," ibid.
- 38. Trader, R. L., "Selection of Odorizer Instrumentation," in "Proceedings of the 32nd Annual Appalachian Gas Measurement Course 1972," Eng. Exp. Sta. Bull. No. 108, 213-19. Morgantown: West Virginia Univ., 1973.
- 39. Lee, H. L., "Design and Operation of Odorization Installations," in "Proceedings of the Twenty-Second Annual Appalachian Gas Measurement Short Course 1962," <u>Tech. Bull.</u> No. 67, 300-09. Morgantown: West Virginia Univ., February 1963.
- 40. Covell, P. L., "Experience in Odorization Shows Need for Standardized Procedures," Amer. Gas J. 171, 27-29 (1949) December.
- 41. Reynolds, L., "Methods of Odorization," in "Proceedings of the Twenty-Ninth Annual Appalachian Gas Measurement Short Course 1969," Eng. Exp. Sta. Bull., 389-91. Morgantown: West Virginia Univ., 1970.
- 42. Lee, H. L., op. cit.
- 43. Newby, A. B. and Wilby, F. V., "An Improved Odorizing Integrator," Proc. Pac. Coast Gas Assn. 48, 112-16 (1957).
- Vlasek, H. C., "Design of an Automated Odorizer," A. G.A. Oper. Sect. Proc. 1968, 68-D-71.
- 45. Buczek, F. L., "Procedure for Determination of Fuel Gas With Air Dilution Apparatus," A.G.A. Oper. Sect. Proc. <u>1966</u>, 66-P-472.

- 46. Whitehead, A. L., "Development of an Optimum Odorization Program." Paper presented at the IGT Odorization Symposium, Chicago, March 1971.
- 47, Lehman, E. A., "Investigation of Odor Complaints," ibid.
- 48. Loper, B. H., op. cit.
- 49. Denham, J. P., "Summary of Questionaire on Method for Odor Level Determinations," A.G.A. Oper. Sect. Proc. 1964, 64-P-145
- 50. Mitchell, R. D., "Odorization Encapsulation Education," A.G.A. Oper. Sect. Proc. 1970, 70-D-12.
- 51. Trittschuh, J. O., "Encapsulated Mercaptan Used to Educate Customers," ibid., 70-D-10.
- 52. Niederer, E., "Safe-T-Sniff Bill Inserts," ibid., 70-D-5.
- 53. Plunkett, G. R., "Modern Odorant Handling Techniques," in <u>Proceedings of the Forty-Eighth Southwestern Gas Measurement Short Course</u>, 21. Norman: Univ. of Oklahoma, 1973.
- 54. Woolfall, G. E., "Accidental Overodorization, Spills, Drum Cleaning and Vapor Control.! Paper presented at the IGT Odorization Symposium Chicago, March 1971.
- 55. Coryell, R. I., "Odorization Technique in New York City," Gas 33, 45-49 (1957) November.
- 56. Harvey, I. W., "Handling Odorants," Gas 45, 70-72, 76, 78, 80 (1969) May.
- 57. Woolfall, G. E., op. cit.
- 58. Ormston, R. H., "Instrumentation, Installation and Operation of Various Odorization Equipment," in "Proceedings of the 16th Annual Appalachian Gas Measurement Short Course = 1956," Eng. Exp. Sta. Bull., 390-402. Morgantown: West Virginia Univ., 1957.
- 59. Dunkley, W. A., "New Gas Odorizer Buildings in Memphis," Gas Age 106, 13-15,58,60 (1950) September,
- 60. Wilby, F, V., "Relation of Odorants to Corrosion." Paper presented at the IGT Odorization Symposium, Chicago, March 1971.
- 61. Clark, J. C., "Experience in Internal Corrosion in Copper Services," ibid.

- 62. Kruger, R. E., "Organic Sulfur Committee Report of Corrosion Survey," A.G.A. Proc. 1939, 517-58.
- 63. Wilby, F. V., op. cit.
- 64. Andreen, B. H. and Kroencke, R. L., "Stability of Mercaptans Under Gas Distribution System Conditions," A. G. A. Oper. Sect., Proc. 1964, 64-P-136.
- 65. Johnson, J. L., "Kinetics of Odor Fading." Paper presented at the A.G.A. Basic Research Symposium, Chicago, March 1967.
- 66. Miller, S. A., Kaeplin, J. A. and Viswanath, D. S., Survey of the Chemistry of Odorant Compounds [A.G.A. Catalog No. OR/53]. New York (Arlingtor 3.): American Gas Association, 1961.
- 67. Olsen, A. W., "Masking of Odorants," A.G.A. Oper. Sect., Proc. 1960, CEP-60-18.
- 68. Coryell, R. L., "Supplemental Odorization Practices." Paper presented at the IGT Odorization Symposium, Chicago, March 1971.
- 69. Coryell, ibid.
- 70. Wicht, A. H. and Deutsch, I., "Factors Affecting Stability of Odorants in Gas, "A, G, A, Oper. Sect., Proc. 1959, CEP-59-2.
- 71. Tarman, P. B. and Linden, H. L., "Soil Adsorption of Odorant Compounds," IGT Res. Bull. No. 34, Chicago: Institute of Gas Technology, 1964.
- 72. Cable, R. C., "A Pilot Plant Study of Gas Odorant Adsorption by Various Soils," M.S. Thesis, Texas College of Arts and Industries, Kingsville, May 1952.
- 73. Olsen, A. W., op. cit.
- 74. Holtz, L., معم عنه.
- 75. Lehman, E. A., op. cit.
- 76. Whitehead, A. L., "Development of an Optimum Odorization Program," op. cit.
- 77. Nevers, A. D. and Oister, W. H., "Problems in the Critical Comparison of Odor Intensities," A. G. A. Oper. Sect. Proc. 1965, 65-P-126.
- 78. McClure, J. S., "Odorant Concentration as Compared to Odor Intensity," A.G.A. Oper. Sect. Proc. 1960, CEP-60-10.
- 79. Dotterweich, F. H., "Natural Gas Odorants," Gas Age 105, 23-24, 51-52, 54 (1950) June.
- 80. Wilby, F. V., "Variation in Recognition Odor Threshold of a Panel," J. Air Pollut. Contr. Assn. 19, 96-100 (1969) February.

- 81. Deininger, N. and McKinley, R. W., op. cit.
- 82. Ripperger, W., "Compositions, Properties, and Chemical Stability of Odorants," Gas und Wasserfach 108, 933-36 (1967) August 18 (German text).
- 83. Kniebes, D. V., Chisholm, J. A. and Stubbs, R. C., "Relative Odor Intensities of Sulfur Compounds Near Their Threshold Concentrations," Paper presented at the American Society of Heating, Refrigerating and Air-Conditioning Engineers Symposium on Odors and Odorants: The Engineering View, Chicago, January 27-30, 1969.
- 84. Leonardos, G., Kendall, D. and Barnard, N., "Odor Threshold Determinations of 53 Odorant Chemicals," J. Air Pollut, Contr. Assn. 19, 91-95 (1969) February.
- 85. Nevers, A. D., op. cit.
- 86. McClure, J. S., op. cit.
- 87. Dravnieks, A., "Properties of Olfactory Systems." Paper presented at the IGT Odorization Symposium, Chicago, March 1971.
- 88. Amoore, J. E., "Odor Blindness as a Problem in Odorization," A.G.A. Oper. Sect. Proc. 1968, 68-D-73.
- 89. Wilby, F. V., "The Odor Comparator An Improved Instrument for Quantitative Odor Measurement," A.G.A. Oper. Sect. Proc. 1964, 64-P-225.
- 90. Durfee, R. A., "Appraisal of Odor-Measurement Technique," J. Air Pollut. Contr. Assn. 18, 472-74 (1968) July.
- 91. Sullivan, D. C., Adams, D. F. and Young, F. A., "Design of an 'Odor Perception and Objectionability Threshold' Test Facility," in Atmospheric Environment, Vol. 2, 121-33. United Kingdom: Pergamon Press, 1968.
- 92. "Putting the Nose to the Test," Chem. Week 112, 35-36 (1973) March 14.
- 93. Cain, W. S., "Perception of Odor Intensity and the Time-Course of Olfactory Adaptation," ASHRAE Trans. 80, Part I, 53-75 (1974).
- 94. Kerka, W. F. and Humphreys, C. M., "Temperature and Humidity Effect on Odor Perception," <u>Heat.</u>, <u>Piping Air Cond.</u> <u>J</u>. <u>28</u>, 129-36 (1956).
- 95. Sullivan, F., "Sensory Evaluation of Odor Problems," A. G.A. Oper. Sect. Proc. 1969, 69-D-36.
- 96. Nevers, A. D., "How Odorants Are Evaluated by Use of New Apparatus," Amer. Gas J. 182, 20-23 (1955) February.

- 97. White, C. E., "New Instrument Designed to Disclose Odor Concentration Levels in Gas," Proc. Pac. Coast Gas Assn. 42, 100-03 (1951).
- 98. Wilby, F. V., "Portable Odorometer and Method for Measuring the Odor Level of Odorized Gas," Proc. Pac. Coast Gas Assn. 42, 104-08 (1951).
- 99. Gascioli, A. F. and Coryell, R. L., "New Odorometer Shows Good Results," Gas Age 113, 9, 10, 52 (1954) January 28.
- 100. Gilkinson, R. W., "Rocheter Gas Develops a Portable, Lightweight Battery-Operated Odorometer," Gas 36, 67-69 (1960) December.
- 101. Austin, R. R., Percy, L. E. and Escher, E. E., "The Automatic Recording Titrata and Its Application to the Continuous Measurement of the Concentration of Organic Sulfur Compounds in Gas Streams," A.G.A. Proc. 1949, 505-15.
- 102. Mason, D. M., "The Titrilog: Its Application to Odorization Problems," Amer. Gas J. 184, 18-20 (1957) August.
- 103. Austin, R. R., "A New Recording Electrolytic Titrator," A. G.A. Oper. Sect. Proc. 1965, 65-P-121.
- 104. Austin, R. R. and Robison, J. R., "Determination of Hydrogen Sulfide and Total Sulfur by Titration Methods," in Proceedings of the Forty-Seventh Annual Southwestern Gas Measurement Short Course, 262-69.

 Norman: Univ. of Oklahoma, 1972.
- 105. Andreen, B. H., Kniebes, D. V. and Tarman, P. B., "Instrumental Methods of Analysis for Odorant Compounds in Natural Gas," IGT Tech.

 Rep. No. 7 for Project P-39. Chicago: Institute of Gas Technology,

 July 1963.
- 106. Wilby, F. V., "Comparison of Methods of Analysis for Sulfur in Natural Gas," A.G.A. Oper. Sect. Proc. 1966, 66-P-241.
- 107. Spencer, C. F., Baumann, F. and Johnson, J. F., "Gas Odorants Analysis by Gas Chromatography," Anal. Chem. 30, 1473-74 (1958) September.
- 108. Andreen, B. H. and Kniebes, D. V., "Determination of Sulfur Compounds in Natural Gas by Gas Chromatography," A. G.A. Oper. Sect. Proc. 1962, CEP-62-13.
- Wilby, F. V., !'Determination of Sulfur Compounds in Natural Gas by Gas Liquid Chromatography Using Low-Temperature Sample Concentrations, Temperature Programming and Microcoulometric Detector (A Panel), "A.G.A. Oper. Sect, Proc. 1965, 65-P-136.
- 110. Gibbons, P. A. and Goode, K. A., "Sulfur Selective Detector in Natural Gas Chromatography," Gas. I. 336, 27-29 (1968) October 9.

- 111. Goode, K. A., "Gas Chromatographic Determination of Sulfur Compounds in North Sea Natural Gas by Flame Photometric Detector,"

 J. Petrol. Inst. <u>56</u>, 33-41 (1970) January.
- 112. Kniebes, D. V., Chisholm, J. A. and Stubbs, R. C., "An Instrument for Direct Measurement of Odor Level in Natural Gas," A. G.A. Oper. Sect. Proc. 1969, 69-D-69.
- 113. Kniebes, D. V., Chisholm, J. A. and Stubbs, R. C. (assigned to Institute of Gas Technology), "Method for Measuring Odor Level in Natural Gas," U.S. Patent 3,686,930 (1972) August 29.
- 114. Kutzleb, R. E., "The Odotron," in "Proceedings of the 32nd Annual Appalachian Gas Measurement Course 1972," Eng. Exp. Sta. Bull. No. 108, 207-212. Morgantown: West Virginia Univ., March 1973.
- 115. Stevens, R. K. et al., "Gas Chromatography of Reactive Sulfur Gases in Air at the Parts-per-Billion Level," Anal. Chem. 43, 827-31 (1971) June.
- 116. Stubbs, R. C., "Response of the Flame Photometric Detector to Sulfur Compounds." Paper presented at the **IGT** Odorization Symposium, Chicago, March 1971.